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Studies in Gujarat Cottons, Part IV

Hybrids between Broach-deshi and Goghari Varieties of Gossypium herbaceum

BY

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STUDIES IN GUJARAT COTTONS, PART IV.

HYBRIDS BETWEEN *BROACH-DESHI* AND *GOGHARI* VARIETIES OF *GOSSYPIUM HERBACEUM*.

BY

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(Received for publication on 9th November, 1926.)

In previous Memoirs[1] the characters of the three main varieties (*Broach-deshi*, *Goghari*, and *Wagad*) of *Gossypium herbaceum* as grown in Gujarat have been described, and an account of a number of representative strains has been given. The first variety (*Broach-deshi*), taken generally, is characterized by a fairly long staple, and by a relatively low ginning percentage, while the second (*Goghari*) usually gives a short staple rough cotton, which possesses a high ginning percentage. The advantage which would accrue if the longer staple of the best strains of the former could be combined with the high ginning of the latter was obvious, and soon after pure strains had been definitely isolated, the crossing of suitable pure types was undertaken in 1919-20. This crossing has not only led to types with the combination of characters desired, but has provided a considerable amount of interesting material relative to their behaviour on crossing, of which it is proposed to give an account in the present Memoir.

I. The material for crossing.

The general characters of *Goghari* cotton given in the author's previous Memoir were based on the types as grown at Broach. These differ slightly when strains of this cotton are grown at Surat, thirty miles further south, and with a generally more moist and longer season. The following description of the types used are from the material actually employed for crossing as grown at Surat where the work was done.

[1] *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XI, No. 4 (1921); Vol. XII, No. 5, 1924; and Vol. XIV, No. 2, 1926.

Broach-deshi Types. Two of the pure types, isolated by the author, were used as follows :—

1. *Type 1027A. L. F.* This type is valued not only because it has the longest staple of any hitherto isolated from Gujarat cottons, but also because of the silky character of its fibres and their creamy colour. The plants of this strain are of a bushy character, but the first fruiting branch is found at a comparatively high node (16 to 20) on the main stem. The leaves are particularly dark green and leathery, at the beginning of the cold weather. The bolls are large and tapering, and the boll index * is, hence, low compared with other types. It usually lies between 75 and 80.

The length of the lint varies in different years from 22½ to 29 millimeters, but in any year it is always higher by from 7 to 12 millimeters than the *Goghari* type with which it is crossed. The lint index ranges from 30 to 35 milligrammes per 100 seeds, and the ginning percentage has varied during a series of six years from 33·5 to 37·0 per cent.

2. *Type I. A. Cylindrical Boll.* This strain of cotton has special value because of its high and constant yield, its high ginning percentage, and its good staple.

The plants are more bushy than any other *Broach-deshi* strain isolated, and it has more markedly hairy leaves. The first fruiting branch is found practically at the same level as in 1027 A. L. F.—about the 16th to the 20th node on the main stem. The bolls are cylindrical, that is to say, they taper only slightly and the boll index varies from 80 to 84.

The length of the lint varies in different years from 19½ to 26½ millimeters, but in any year it is always higher by from 4 to 7 millimeters than the *Goghari* type with which it is crossed. The lint index ranges from 35½ to 41½ milligrammes per 100 seeds, and the ginning percentage has varied from 37 to 39 per cent. in a series of six years.

Goghari Type. The crossing was done with one single *Goghari* type, which was chosen simply on account of its abnormally high ginning percentage, which in fact varies from 46 to 51 per cent.

This *Goghari* type is not a very bushy strain. The primary fruiting branches are very vigorous ; and are borne at a very low point on the main stem, that is to say, at between the 14th and 17th node. The bolls are almost round with a boll-index of from 87 to 91.

The length of the lint is very low, varying from 13½ to 19½ millimeters, and hence the cotton is very inferior. The lint index ranges from 46 to 60 milligrammes per 100 seeds, and the ginning percentage has varied (as already stated) from 46 to 51 per cent. In this matter of ginning percentage, the figure is higher than any known strain of *Gossypium herbaceum*.

It will be seen from these descriptions that we have two very markedly different kinds of cotton plant, and a study of the actual figures during the last six years

* The boll-index is the maximum diameter × 100 divided by the maximum length of the bolls.

for the types to be crossed reveals the fact that between either of the *Broach-deshi* parents and the *Goghari* parent, there is a significant difference in the following characters :—

1. The node on the main stem from which the first sympodium arises.
2. The number of monopodia on the main stem.
3. The greatest diameter of the bolls.
4. The boll-index.
5. The length of staple on the middle of the seed.
6. The lint index.
7. The seed weight (only in the case of 1-A cylindrical Boll and Goghari).
8. The ginning percentage.

The other characters in which these types differ are (*a*) the extent of opening of the bolls, which is very difficult to measure satisfactorily, (*b*) the fuzziness or nakedness of the seed surface, in which the difference is, in any case, one of degree, but which varies from boll to boll, and (*c*) the way in which the lint hairs are strongly or loosely attached to the seeds. No attempt was made to study these characters statistically.

II. The characters of the hybrid plants.

There has been much study of the results of crossing among cottons , but most of these have been of crosses made between different species of *Gossypium*. Thus the results of crossing *Gossypium barbadense* (Sea Island cotton) and *Gossypium hirsutum* (Upland American) on the one hand, and *Gossypium peruvianum* (Egyptian) and Upland American have been carefully studied. In India we have the studies by Leake[1] of crosses of *Gossypium neglectum* with *Gossypium arboreum* and *Gossypium indicum*, and by Kottur[2] of a cross between *Gossypium neglectum* and *Gossypium herbaceum* (Kumpta cotton). Little is known, on the other hand, of the behaviour of crosses between types within the same species. Studies have, however, been made by Kearney[3] in Egyptian cottons and by Longfield[4] in Sea Island cottons as grown in the West Indies.

The original crosses on which the results to be described are based were made in 1919-20. The male parent in each case was the Goghari E-5, the female being the *Broach-deshi* 1027 A. L. F. or I-A. Cylindrical Boll. Since 1920-21, the parents have been always grown side by side with the various generations of the cross. In the first generation (F_1) four dibbles from each crossed boll were planted,

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[1] Leake and Ram Prasad. Studies in Indian cottons. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 4 (1914).

[2] Kottur. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3 (1923).

[3] Kearney. A study of hybirds in Egyptian cotton. *Amer. Nat.*, Vol. 52, p. 491 (1918).

[4] Longfield. Experiments with hybird cottons. *Rep. Agri. Expt. Station St. Croix*, 1913 -14 (1915)

and it was soon evident that considerably greater vigour had resulted in the plants. This was shown in the height of the plant and in the development of the branches, resulting in high yield. The actual figures of the yield of seed-cotton from one hundred and twenty dibbles were as follows :—

	Yield of seed cotton in lb. per 120 dibbles (3′ × 3′).
1027 A. L. F	13·7
I-A Cylindrical Boll	15·2
Goghari E-5	11·9
1027 × E-5	17·2
I-A × E-5	17·3

No new extra-parental characters were observed in the progeny of the crosses and no sterility was seen. No individual plant in the second generation of the cross (F_2) was seen which varied *widely* from the type of either parent.

A. The node on the main stem from which the first sympodium arises.

The importance of this vegetative character is considerable, as it determines in some measure the type of plant which ultimately grows. But it is manifestly dependent very largely on the environmental conditions of any year, and it is far more variable in any pure strain in one season than another. The mean figure for the mean node number for the three strains used as parents of the cross and the co-efficient of variation is shown below :—

Mean node number of parents of the cross.

Year	1027 A. L. F.		1-A Cylindrical Boll.		Goghari E-5.	
	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation
1920-21	15	13·0±0·6	15	11·0±0·3	..	..
1921-22	20	7·6±0·3	20	6·0±0·3	17	7·9±0·5
1922-23	16	9·6±0·4	17	8·1±0·3	14	16·5±0·6*
1923-24	17	8·9±0·4	17	8·2±0·4	14	10·3±0·5
1924-25	17	12·9±0·5	17	11·2±0·4	14	14·9±0·6
1925-26	17	9·6±0·4	17	8·2±0·3	14	9·9±0·4

It is evident from these figures that the difference between the *Broach-deshi* types used as female parents and the *Goghari E-5* used as the male parent, in this

* An irregularly germinated crop.

matter is significant, and it is interesting to follow the behaviour of the character when they are crossed. It is curious to note the much greater variation shown each year by the *Goghari* strain than by the others.

Details as to the behaviour of this character in the first generation of the cross (F_1) was wanting, but the second generation (F_2) shows a very wide variation. The following table gives a frequency distribution of the progeny in each case, compared with that of the parents of the crosses, so far as the node number of the first sympodium is concerned. The figures are taken for 500 plants in each case.

Frequency of each node number.

Node number	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
13-14	..	..	9	4	..
15-16	18	..	136	78	68
17-18	61	90	**255**	**259**	**277**
19-20	**225**	**320**	100	136	133
21-22	175	90	..	21	22
23-24	21	..	..	2	—

The mean node number in each case was in 1921-22 (for the parents and the second generation of the cross).

1027 A.L.F.	20·4
1-A Cylindrical boll	19·5
Goghari E-5	17·4
1027 × Goghari cross	17·9
1-A × Goghari cross	17·2

Out of the progeny, the seed from two or three plants self-fertilized were continued in the third generation. They were selected not on account of the character, now under discussion, but because of their seed and fibre characters. The plants selected had node numbers as follows :—

1027 × Goghari cross—	
Plant 5	18
Plant 6	18
1 A × Goghari cross—	
Plant 1	18
Plant 5	17
Plant 9	**19**

Their progeny in 1922-23 gave the following distribution for 100 plants in each case, the figures for the parents also being given.

NODE NUMBERS.

Frequency distribution with different types.

	9-10	11-12	13-14	15-16	17-18	19-20
1027 A. L. F.	..	7	11	45	17	..
1-A Cylindrical boll	..	1	2	15	60	22
Goghari E-5	11	21	9	52	6	..
1027 × Goghari cross—						
Plant 5	2	34	2	36	26	..
Plant 6	..	6	6	71	17	..
1-A × Goghari cross—						
Plant 1	1	21	20	27	29	2
Plant 5	4	10	29	53	4	..
Plant 9	..	..	4	67	29	..

One plant out of each type of the cross was now selected for propagation in the next generation, the plants selected having node numbers as follows :—

1027 A. L. F. × Goghari cross—	
Plant 5	15
Plant 6	17
1-A × Goghari cross—	
Plant 1	15
Plant 5	16
Plant 9	15

Again, the progeny of these plants gave the following distribution for 100 plants in each case, in the fourth generation of the cross.

NODE NUMBERS.

Frequency distribution with different types.

	11-12	13-14	15-16	17-18	19-20
1027 A. L. F.	..	7	38	**46**	9
1-A Cylindrical boll	..	6	**46**	37	11
Goghari E-5	5	**44**	39	12	..
1027 × Goghari cross—					
Plant 5	5	19	**47**	24	5
Plant 6	..	11	**54**	33	2
1-A × Goghari cross—					
Plant 1	2	34	**55**	9	..
Plant 5	3	17	**58**	21	1
Plant 9	7	27	**57**	9	..

Similar selection of a single plant has been done for the two following generations with results as follows :—

FIFTH GENERATION. (F_5).

A. NODE NUMBER OF PLANT SELECTED AS PARENT.

1027 × Goghari cross—	
Plant 5	15
Plant 6	18
1-A × Goghari cross—	
Plant 1	16
Plant 5	16
Plant 6	14

B. Node numbers of progeny.

Frequency distribution with different types.

	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26
1027 A. L. F.	..	3	11	23	37	23	3	..	..
1-A Cylindrical boll	..	1	5	21	40	27	6	..	..
Goghari E-5	3	19	25	29	23	1	..	..	..
1027 × Goghari cross—									
Plant 5	..	4	4	31	44	17	..	..	..
Plant 6	..	2	10	27	48	12	1	..	..
1-A × Goghari cross—									
Plant 1	..	1	9	26	50	13	1	..	..
Plant 5	..	..	..	..	7	20	50	18	5
Plant 9	2	4	26	44	22	2	..	..	..

SIXTH GENERATION. (F_6).

A. Node number of plant selected as parent.

1027 × Goghari cross—
- Plant 5 16
- Plant 6 16

1-A × Goghari cross—
- Plant 1 . . . . . Not available (Pruned).
- Plant 5 22
- Plant 6 . . . . . Not available (Pruned).

B. Node numbers of progeny.

Frequency distribution with different types.

	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24
1027 A. L. F.	..	..	2	4	30	52	11	1	..
1-A Cylindrical boll	..	..	..	2	30	51	16	1	..
Goghari E.-5	1	4	31	53	10	1	..	..	..
1027 × Goghari cross—									
Plant 5	..	..	1	21	48	29	1	..	..
Plant 6	..	..	1	15	51	29	4	..	..
1-A × Goghari cross—									
Plant 1	..	..	..	15	60	22	3	..	..
Plant 5	..	..	..	..	3	26	53	16	2
Plant 9	..	1	7	63	25	4	..	..	..

It will be seen that while there is full evidence of the hereditary nature of the character in question, it is only in the fifth and sixth generation (F_5 and F_6) of the cross that we have been able to separate types, by the method adopted, which breed true, that is to say, which give progeny *not more variable than the original parents*. This has, however, been reached in all cases now, as is shown by the following mean figures in the two years, with the coefficient of variation :—

	1924-25		1925-26	
	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation
1027 A. L. F.	16·9	12·9±0·5	16·8	9·6±0·4
1-A Cylindrical boll	17·5	11·2±0·4	17·1	8·2±0·3
Goghari E-5	14·5	14·9±0·6	14·0	9·9±0·4
1027 × Goghari cross—				
Plant 5	16·8	10·3±0·7	15·7	9·9±0·3
Plant 6	16·6	10·3±0·5	16·0	9·1±0·4
1-A × Goghari cross—				
Plant 1	16·8	10·3±0·5	15·7	8·5±0·3
Plant 5	21·4	8·4±0·4	19·2	7·8±0·5
Plant 9	15·2	11·8±0·5	13·9	9·0±0·3

These figures show that of the five selections made in the F_2 generation and continued by single plant selections in succeeding generations all have ceased splitting and breed true by the test used. Of these

(1) Three have the same node number as the female parent (1027 A. L. F. or 1-A Cylindrical Boll as the case may be) *viz.* (Plants 5 and 6 of the 1027 × Goghari cross and Plant 1 of the 1-A × Goghari cross) ;

(2) One has the same node number as the male parent (Goghari E-5). This is Plant 9 of the 1-A × Goghari cross.

(3) One gives higher values than either of the parents (Plant 5 of the 1-A × Goghari cross) and has done so from the fifth generation (F_5).

The last is an interesting case, and of some importance. It shows that we are dealing with a complex character, and it is possible that this is one of the cases where the theory of cumulative factors might serve to explain the results. Further, as in lower Gujarat it is rather an advantage for the first sympodial branch to be high (so as to leave ample chance for a satisfactory development of primary monopodia), it shows that the method followed is capable of leading to improved types, as in the case of the plant in question.

B. The greatest diameter of the bolls.

The size of the bolls is important in every type of cotton, and other things being equal, the type which has the largest bolls will always be preferred. The difference between the average of the determinations of the maximum diameter of the bolls of the parents of the cross is significant, and is shown in various years in the following table.

Greatest diameter of the bolls.

	1027 A. L. F.		1-A Cylindrical Boll.		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	mm.		mm.		mm.	
1921-22 . . .	25·9	3·0±0·2	25·2	2·5±0·2	28·6	3·1±0·3
1922-23 . . .	26·5	3·3±0·3	..	..	28·5	2·9±0·2
1923-24 . . .	27·1	2·2±0·1	25·3	3·0±0·2	28·5	2·6±0·2
1924-25 . . .	28·1	3·5±0·2	26·8	3·6±0·2	29·2	3·6±0·2
1925-26 . . .	25·4	3·5±0·2	25·2	3·0±0·1	27·0	2·8±0·1

Details of the behaviour of this character in the first generation of the cross (F_1) are wanting, but the second generation shows very wide variation. The following table gives a frequency in each case, compared with that of the parents of the crosses. The figures are given for 100 plants in each case.

Frequency distribution with each type.

	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
Diameter in mm.—					
23-24	..	3	..	..	1
24-25	15	33	..	3	4
25-26	36	**58**	..	12	18
26-27	**46**	6	3	**32**	**37**
27-28	3	..	18	29	27
28-29	..	..	**49**	19	11
29-30	..	..	24	3	2
30-31	..	..	6	1	..

The mean diameter in each case was, in 1921-22, for the F_2 generation.

	mm.
1027 A. L. F.	25·9
1-A Cylindrical boll	25·2
Goghari E-5	28·6
1027 × Goghari cross	27·1
1-A × Goghari cross	26·8

The distribution in the F_2 generation in the frequency table given above is almost a normal frequency curve (suggesting a complex character) ; the range covers the extremes of both parents, and there is very little overlapping between the figures obtained with the two parents.

The selections—two plants of the 1027 × Goghari cross, and three plants of the 1-A × Goghari cross—were treated exactly as described previously, and the behaviour of single plant selections in the succeeding generations is shown below.

THIRD GENERATION (F_3).

In this generation only the 1-A × Goghari cross was studied, and the figures for 1-A Cylindrical boll are missing. The figures obtained were, however, as follows :—

1. Diameter of bolls of the parent plants.

	mm.
1-A × Goghari cross—	
Plant No. 1	28
Plant No. 5	27

2. Maximum boll diameter (in mm.).

Frequency distribution with different types.

	24-25	25-26	26-27	27-28	28-29	29-30	30-31
Goghari E-5	..	..	..	30	40	27	3
1-A × Goghari cross—							
Plant 1	..	13	51	26	10	..	..
Plant 5	2	6	27	43	19	3	3

FOURTH GENERATION (F_4).

1. Diameter of bolls of the parent plants.

	mm.
1-A × Goghari cross—	
Plant 1	28
Plant 5	26

The others were not recorded.

2. Maximum boll diameter in mm.

Frequency distribution with different types.

	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31
1027 A. L. F. . .	5	23	56	16	..	..	..	..
1-A Cylindrical boll .	5	23	39	23	10	..	..	..
Goghari E-5 . .	..	..	..	1	25	51	23	..
1027 × Goghari cross—								
Plant 6 . . .	..	..	..	..	7	38	41	14
1-A × Goghari cross—								
Plant 1 . . .	..	2	2	25	41	28	2	
Plant 9 . . .	3	12	22	28	27	8	..	

FIFTH GENERATION (F_5).

1. Diameter of bolls of the parent plants.

	mm.
1027 × Goghari cross—	
Plant 6	28
1-A × Goghari cross—	
Plant 9	26

The others were not recorded.

2. Maximum boll diameter (in mm.)

Frequency distribution with different types.

	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34
1027 A. L. F. . .	..	..	9	38	39	11	2	1	..	..
1-A Cylindrical boll .	4	14	44	29	8	1	..	..	..	..
Goghari E-5 . .	..	..	..	16	28	34	19	3	..	..
1027 × Goghari cross—										
Plant 6 . .	..	..	..	2	3	31	37	14	6	7
1-A × Goghari cross—										
Plant 1 . .	2	5	26	53	14	..	..	..	..	..
Plant 5 . .	..	2	7	19	37	26	8	1	..	.
Plant 9 . .	..	1	5	39	45	9	1	.	..	..

SIXTH GENERATION (F_6).

1. Diameter of bolls of the parent plants.

	mm.
1027 × Goghari cross—	
Plant 6	28
1-A × Goghari cross—	
Plant 1	29
Plant 5	30
Plant 9	28

2. Maximum boll diameter (in mm.)

Frequency distribution.

	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31
1027 A. L. F.	8	19	47	25	1	..	..	..
1-A Cylindrical boll	5	31	51	13	..	..	..	..
Goghari E.-5	..	1	5	45	42	7	..	..
1027 × Goghari cross—								
Plant 5	..	..	13	43	40	4	..	..
Plant 6	..	..	..	4	29	47	19	1
1-A × Goghari cross—								
Plant 5	1	12	25	51	11	..	..	..
Plant 9	..	6	35	43	11	..	..	..

We have again been able to separate types in the fifth and sixth generations of the cross, which breed true and whose variability seems to have reached a stable position. The mean values and the coefficient of variation for the three final years are given below :—

	1923-24		1924-25		1925-26	
	Mean diameter mm.	Coefficient of variation	Mean diameter mm.	Coefficient of variation	Mean diameter mm.	Coefficient of variation
1027 A. L. F.	25·4	2·3±0·1	25·1	3·6±0·2	25·4	3·6±0·2
1-A Cylindrical boll	25·7	2·9±0·2	26·8	3·6±0·2	25·2	3·0±0·1
Goghari E-5	28·5	2·6±0·2	29·2	3·6±0·2	27·0	2·8±0·1
1027 × Goghari cross—						
Plant 5	..	..	..	..	26·8	2·9±0·8
Plant 6	29·3	3·7±0·3	30·3	3·9±0·3	28·4	2·8±0·2
1-A × Goghari cross—						
Plant 1	27·5	3·4±0·2	27·2	3·2±0·2	..	..
Plant 5	..	..	28·6	4·4±0·3	26·1	5·0±0·2
Plant 9	26·4	4·7±0·4	28·1	3·0±0·2	26·2	2·9±0·1

These figures show that of the five selections made in the F_2 generation, and continued by single plant selections in succeeding generations, four have now come to breed true, while one is still doubtful by the test used. Of these,

(1) One has the same type as the female parent (1-A × Goghari cross plant 1).
(2) One has the same type as the male parent (1027 × Goghari cross plant 5).
(3) One shows a higher value than either parent (Plant 6 of the 1027 × Goghari cross).
(4) Two show types intermediate between the two parents, *viz.*, 1-A cross plants 5 and 9 out of which the purity of the former is still doubtful.

It may, therefore, be concluded that the character under study is hereditary, but is, again, a complex one, because of the occurrence of a segregate with a higher value than either parent.

C. Shape of bolls.

The question as to whether the shape of bolls is hereditary, that is to say, whether a round bolled type of cotton or a long-bolled type gives progeny true to this character, is one which has been many times studied. The figure used as an indication of shape is the boll index, or, in other words, the relation of the maximum breadth of the boll to its length. It will be seen that a high boll index means a *round* boll; a low boll index means a *long* boll.

Studying the shape of the bolls by the use of this boll index, Kearney[1] found that in a cross between an Egyptian (Pima) and an Upland American (Holdon) cotton, the character was a complex one composed of more than one hereditary factor, but the same worker[2], when investigating a cross between two Egyptian cottons (Gila and Pima) showed that the F_2 generation was not more variable than the F_1 generation, and thus the shape of the boll was not inherited as a Mendelian character at all. This seemed also to be confirmed by the behaviour in the F_3 generation. In Upland-Egyptian cotton hybrids, Balls[3] found a similar result to that of Kearney noted above. McLendon,[4] working with Upland-Sea-Island hybrids, concluded that the short thick type of boll is recessive, although he did not find the long slender type to be fully dominant.

Apart from its scientific interest, the shape of the boll is important to us as a means of rapidly identifying a type of cotton, and so its behaviour on crossing has a very special interest. The actual figures for the mean boll index in the parents of the cross under study, with the variability as shown by the coefficient of variation is shown in the following table.

[1] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull* 1164 (1923).

[2] Kearney. Hybrids in Egyptian cotton. *Am. Nat.*, Vol. 52 (1918).

[3] Balls. The cotton plant in Egypt, p. 162.

[4] McLendon. Mendelian inheritance in cotton hybrids. *Georgia Agri. Expt. Sta. Bull.* 99 (1912).

Boll index.

	1027 A. L. F.		1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
1921-22	75·0	3·0±0·3	80·9	2·9±0·2	90·7	2·1±0·2
1922-23	77·0	2·4±0·2	..	..	91·1	2·2±0·2
1923-24	77·0	2·1±0·1	80·4	1·5±0·1	86·8	2·6±0·2
1924-25	79·2	1·8±0·1	84·0	2·0±0·9	90·1	2·2±0·1
1925-26	76·5	2·5±0·1	82·7	2·0±0·1	89·7	2·9±0·1

There is thus a very marked difference between the shape of the bolls in the strains crossed, and the behaviour of the cross in the following generations may be followed. In the first generation (F_1) measurements of the character were not recorded, but in the second (F_2) generation the means and the coefficient of variation were as follows :—

Boll index—F_2 generation (1921-22).

	Mean value	Coefficient of variation
1027 A. L. F.	75·0	3·0±0·3
1-A Cylindrical boll	80·9	2·9±0·2
Goghari E-5	90·7	2·1±0·2
1027 × Goghari cross	84·9	4·3±0·1
1-A × Goghari cross	85·7	4·0±0·1

The mean figures for the crossed types are very nearly the average of the parental values,—though the 1027 × Goghari cross goes a little towards greater diameter. The coefficient of variation is, however, considerably higher than that of either parent, as would be expected with the segregation of a hereditary character.

The distribution of the value of this boll index in the F_2 generation is shown below :—

Frequency of boll index value.

	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
68-72	6	..	..	1	..
72-76	52	3	..		..
76-80	42	30	..	9	5
80-84	..	61	..	30	27
84-88	..	6	3	43	45
88-92	..	..	73	15	19
92-96	..	..	24	2	4

There is no overlapping between the values for the boll-index in the parents of the 1027 × Goghari cross, and it is only slight between those of the 1-A × Goghari cross. If we take these values below 86 as characteristic of one parent, and those over this figure as characteristic of the other, the figures work out as follows: —

1027 × Goghari cross—

$$\text{Ratio.—} \left\{ \frac{\text{Low boll index}}{\text{High boll index}} \right. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = \frac{1{\cdot}6}{1}$$

1-A × Goghari cross—

$$\text{Ratio.—} \left\{ \frac{\text{Low boll index}}{\text{High boll index}} \right. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = \frac{1{\cdot}15}{1}$$

If these are combined, that is to say, if we consider the inheritance being similar in both cases, the ratio becomes :

$$\frac{\text{Low boll index}}{\text{High boll index}} = \frac{1{\cdot}36}{1}$$

or approximately a ratio of 9 to 7, which would be expected of a complex character with two independently varying factors.

In the succeeding generations, all the types obtained by taking selections from the F_2 generation, and single plant selections of each strain in the following years, go back into one or other of the parental types. The records of the third generation (F_3) are not complete enough to enable us to use them.

FOURTH GENERATION (F_4).

1. Boll index of parent plants.

1-A × Goghari cross—
Plant 1 . . . . . 93·0
Plant 9 . . . . . 80·5

2. Boll index in F_4 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92
1027 A. L. F.	29	69	2	..	..
1-A Cylindrical boll	..	35	65	..	..
Goghari E-5	..	..	10	54	36
1027 × Goghari cross—					
Plant 6	..	9	52	37	2
1-A × Goghari cross—					
Plant 1	..	6	61	27	6
Plant 9	3	37	54	6	.

FIFTH GENERATION (F_5).

1. Boll index of parent plants.

1027 × Goghari cross—
Plant 6 85

1-A × Goghari cross—
Plant 1 . . . . . 82·5
Plant 9 . . . . . 79·5

2. Boll Index in F_5 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92	92-96
1927 A. L. F.	1	73	26	..	..	..
1-A Cylindrical boll	..	1	45	53	1	..
Goghari E.-5	..	..	..	14	67	19
1027 × Goghari cross—						
Plant 6	..	9	59	28	4	..
1-A × Goghari cross—						
Plant 1	..	7	52	36	5	..
Plant 5	..	..	1	16	51	32
Plant 9	..	6	73	21	..	..

SIXTH GENERATION (F_6).

1. Boll index of parent plants.

1027 × Goghari cross—	
Plant 6	78
1-A × Goghari cross—	
Plant 1	80·5
Plant 5	96·0
Plant 9	83·0

2. Boll index in F_6 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92	92-96
1027 A. L. F.	36	56	8	..	..	..
1-A Cylindrical boll	..	5	71	24	..	..
Goghari E-5	..	..	..	30	48	22
1027 × Goghari cross—						
Plant 5	2	34		8	..	..
Plant 6	17	72	11	..	..	..
1-A × Goghari cross—						
Plant 5	..	..	4	19	68	9
Plant 9	..	..	20	57	23	..

On a review of all these figures, it may be stated that there is evidence that the shape of the boll, as indicated by the boll index, is a complex character as already found by both Kearney and Balls. It would seem that it may be composed of two factors.

The further growth of selfed material up to the sixth generation of the cross, shows that the progeny ultimately falls into one or other of the parental types. This is apparently due to the proportionate increase or decrease in both the components of the ratio, *viz.* greater diameter and length of bolls. Out of five cases studied, four had become closely similar to the female parent, with similar variability, and one had approximated to the male parent. The following is a statement of the mean values of the parents and of the final three years of the growing of the cross.

	1923-24		1924-25		1925-26	
	Mean boll index	Coefficient of variation	Mean boll index	Coefficient of variation	Mean boll index	Coefficient of variation
1027 A. L. F.	77·0	2·1±0·1	79·2	1·8±0·1	76·5	2·5±0·1
1-A Cylindrical boll . . .	80·4	1·5±0·1	84·0	2·0±0·1	82·7	2·0±0·1
Goghari E-5	86·8	2·6±0·2	90·2	2·2±0·1	89·7	3·0±0·1
1027 × Goghari cross—						
Plant 5	..	..	..	..	80·8	2·9±0·1
Plant 6	79·3	2·8±0·1	83·1	3·1±0·2	77·8	2·6±0·1
1-A × Goghari cross—						
Plant 1	82·9	2·6±0·2	83·5	3·1±0·2	..	..
Plant 5	..	..	90·5	2·7±0·1	89·3	2·7±0·1
Plant 9	80·4	2·7±0·1	83·4	2·2±0·1	86·1	2·5±0·1

D. Length of staple.

In breeding cotton for the market, the length of the staple becomes one of the dominating considerations, and hence any evidence obtainable as to the nature of this character, and how it behaves in breeding is of very great importance, and many studies have been made upon it. Most of the early workers in India found that long staple is dominant over short staple, and that it behaves as a simple Mendelian character. The results of Fletcher, Fyson, and Kottur agree with this view.[1] McLendon,[2] studying Sea Island Upland hybrids, found no pure dominance, as the first generation (F_1) gave a type intermediate between the parents, and variable. Kearney,[3] studying hybrids between Egyptian (Pima) and Upland (Holdon) cottons, found that the F_1 generation gave staple intermediate between

[1] Fletcher. Mendelian inheritance in cotton. *Journal Agricultural Science*, Vol. II, p. 281 (1907).
Fyson. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. II, No. 6 (1908).
Kottur. Studies of inheritance in cotton, Part I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3 (1923).
[2] McLendon. Mendelian inheritance in cotton hybrids. *Georgia Agri. Expt. Stn. Bull.* 99 (1912).
[3] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull.* 1164 (1923).

the parents, but approached that of the longer parent, while the distribution of the progeny in the F_2 generation indicated that several factors were involved.

Thus the net conclusion from previous work is that while long staple tends to be a dominant character, yet recent investigation suggests that this dominance is not complete, and that the character may be decidedly a complex one.

In the records which follow, the staple was always determined on the middle of the seed, and from ten seeds taken from three bolls representing the whole produce of a plant. The actual figures for the parents, in this character, for a series of years, with the coefficient of variation are as follows :—

LENGTH OF STAPLE.

	1027 A. L. F.		1-A CYLINDRICAL BOLL		GOGHARI E-5	
	Mean mm.	Coefficient of variation	Mean mm.	Coefficient of variation	Mean mm.	Coefficient of variation
1920-21	26	8·7±0·4	22	10·0±0·5	18	12·0±0·6
1921-22	29	7·2±0·6	26	7·2±0·3	20	9·4±0·6
1922-23	29	6·7±0·6	24	8·5±0·4	17	10·8±0·5
1923-24	22	10·1±0·4	20	9·7±0·3	14	11·5±0·4
1924-25	24	9·4±0·4	20	10·8±0·3	16	13·3±0·5
1925-26	23	8·8±0·1	21	8·7±0·1	13	13·2±1·0

This is one of the two characters, therefore, in which there is the greatest difference between the parents, the 1027 A.L.F. representing the best staple among Gujarat cottons while the Goghari E-5 was worthless as a staple cotton. In the first generation (F_1) of the crosses, the distribution and mean of the progeny is shown below.

LENGTH OF STAPLE. F_1 GENERATION.

Frequency distribution in percentage.

	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1027 A. L. F. . .	..	..	..	3	29	**46**	20	2
1-A Cylindrical boll .	..	..	3	39	**42**	16	..	..
Goghari E-5 . .	2	12	42	**44**	..	..	..	..
1027 × Goghari cross .	..	..	..	10	**66**	23	1	..
1-A × Goghari cross .	..	2	28	**55**	14	1	..	..

The F_1 generation is therefore intermediate between the parents, as the means show—

LENGTH OF STAPLE. F_1 GENERATION.

	Mean	Coefficient of variation
	mm.	
1027 A. L. F.	26	8·7±0·4
1-A Cylindrical boll	22	10·0±0·5
Goghari E-5	18	12·0±0·6
1027 × Goghari cross	23	7·7±0·2
1-A × Goghari cross	20	10·2±0·2

The mean of the parents in the 1027 × Goghari cross is 22 and that of the 1-A × Goghari cross is 20, showing how nearly intermediate the F_1 generation is—

SECOND GENERATION (F_2).

The distribution of the value of the staple length in the second generation of the cross is as follows :—

Frequency of length of staple (1921-22).

Staple length mm.	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
13-15	..	..	..	..	4
16-18	..	..	22	4	27
19-21	..	1	68	22	41
22-24	..	14	10	40	23
25-27	20	60	..	31	5
28-30	60	23	..	3	..
31-33	17	22	..	..	..
34-36	3	..	..	..	..

The mean figure and the variability are as follows :—

LENGTH OF STAPLE. F_2 GENERATION.

	Mean	Coefficient of variability
1027 A. L. F.	29	7·2±0·6
1-A Cylindrical boll	26	7·2±0·3
Goghari E-5	20	9·4±0·6
1027 × Goghari cross	23	12·0±0·1
1-A × Goghari cross	20	14·2±0·1

The figures for plants selected as described under previous characters in the next four generations may now be given.

THIRD GENERATION (F_3).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	27
Plant 6	26
1-A × Goghari cross—	
Plant 1	24
Plant 5	23
Plant 9	25

(2) Staple Length in F_3 generation.

Frequency distribution with different types.

	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.	28-30 mm.	31-33 mm.
1027 A. L. F.	..	..	..	..	17	**60**	23
1-A Cylindrical boll	..	1	9	**47**	42	1	..
Goghari E-5	23	**63**	14	..	..	..	..
1027 × Goghari cross—							
Plant 5	..	..	6	25	**57**	12	..
1-A × Goghari cross—							
Plant 1	1	15	**44**	33	7	..	..
Plant 5	1	8	28	**45**	18	..	..
Plant 9	..	1	11	35	**45**	8	..

FOURTH GENERATION (F_4).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	26
Plant 6	25
1-A × Goghari cross—	
Plant 1	24
Plant 5	24
Plant 9	24

2. Staple length in F_4 generation.

Frequency distribution.

	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.
1027 A. L. F.	..	..	6	33	42	19
1-A Cylindrical boll	..	2	30	54	14	..
Goghari E-5	14	58	28	..	..	..
1027 × Goghari cross—						
Plant 6	..	2	11	42	39	6
1-A × Goghari cross—						
Plant 1	1	7	30	47	13	2
Plant 5	..	3	16	45	32	4
Plant 9	1	6	28	49	16	..

FIFTH GENERATION (F_5).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	23
Plant 6	23
1-A × Goghari cross—	
Plant 1	22
Plant 5	22
Plant 9	21

2. Staple length in F_5 generation.

Frequency distribution.

	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.	28-30 mm.
1027 A. L. F.	..	..	2	18	36	**43**	1
1-A Cylindrical boll . . .	..	1	17	57	23	2	..
Goghari E-5	4	36	**40**	20	..	..	..
1027 × Goghari cross—							
Plant 5	..	..	..	10	30	**54**	6
Plant 6	..	..	4	26	**38**	31	1
1-A × Goghari cross—							
Plant 1	..	..	2	33	**45**	20	..
Plant 5	..	1	14	52	31	2	..
Plant 9	..	..	8	**48**	38	6	..

SIXTH GENERATION (F_6).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	26
Plant 6	24
1-A × Goghari cross—	
Plant 1	24
Plant 5	22
Plant 9	23

2. Staple length in F_6 Generation.

Frequency distribution.

	7-9 mm.	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.
1027 A. L. F.	..	..	..	2	28	55	15
1-A Cylindrical boll	..	..	1	12	57	29	1
Goghari E-5	2	25	60	13	..	..	..
1027 × Goghari cross—							
Plant 5	..	..	..	5	29	45	21
Plant 6	..	..	1	14	41	39	5
1-A × Goghari cross—							
Plant 1	..	..	..	7	47	41	5
Plant 5	..	..	..	12	54	32	2
Plant 9	..	..	..	9	47	40	4

Types have again been separated which breed true and whose variability seems to have reached a stable position. The mean values and the coefficient of variation for the two final years are given below.

	1924-25		1925-26	
	Mean staple length	Coefficient of variation	Mean staple length	Coefficient of variation
	mm.		mm.	
1027 A. L. F.	24	9·4±0·4	23	8·8±0·1
1-A Cylindrical boll	20	10·8±0·3	21	8·7±0·1
Goghari E-5	16	13·3±0·5	13	13·2±0·0
1027 × Goghari cross—				
Plant 5	25	8·6±0·2	22	11·0±0·1
Plant 6	23	11·3±0·2	21	12·2±0·0
1-A × Goghari cross—				
Plant 1	22	9·2±0·2	21	8·5±0·4
Plant 5	21	10·5±0·1	21	10·1±0·1
Plant 9	21	10·5±0·2	21	10·3±0·1

All the types isolated from the cross seem now to be pure so far as the purity can be judged by the coefficient of variation. The purity of the strain represented by 1027 × Goghari cross, Plant No. 5, was also tested by determining the correlation between parents and offspring in 44 plants of this type. The coefficient of correlation worked out at —0·004, which shows that there is no correlation and hence the strain is pure.

The purity in each case being clear, it will be noted that of the five types isolated—

(1) three conform almost exactly to the character of the longer staple parent (1027 × Goghari cross, Plant 5, and 1-A × Goghari cross, Plants 5 and 9).

(2) One is slightly inferior to the longer parent (1027 × Goghari cross, Plant 6).

(3) One is distinctly longer in staple than the longer parent (1-A × Goghari cross, Plant 1).

The occurrence of the types which do not conform to the character in either parent makes it very probable that length of staple is a complex character. Further evidence is probably needed to prove this point absolutely, but the facts here presented would make it very probable, and would be of great importance as they would open the possibility of breeding types with a much longer staple than that of either of the parents involved.

There is one point in connection with the staple of these crosses which has not yet been dealt with. The staple, as given, is that of the mean from the middle of the seed. But the cotton is actually a mixture of fibres of very different staple length. The actual proportion of fibres of different lengths, as determined by the Balls Sorter.* in 1924-25 for 1027 A. L. F., and some of the crosses was as follows :—

Frequency distribution.

Length of fibre	1027 A. L. F.	1027 × Goghari cross No. 6	1-A × No. 1	Goghari No. 5	Cross No. 9
mm.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
7·5	0·2	0·7	0·3	0·3	0·4
10·5	1·3	1·6	1·8	1·6	1·6
13·5	2·8	3·4	3·1	3·5	4·1
16·5	4·8	5·4	5·8	6·7	8·0
19·5	9·1	11·2	11·3	12·9	19·6
22·5	18·7	20·4	23·8	23·3	*25·7*
25·5	*36·7*	*31·7*	*36·0*	*27·6*	21·0
28·5	22·5	22·1	16·6	19·5	17·3
31·5	3·4	3·8	1·3	4·6	2·3
34·5	0·4	..	..	..	..
37·5	0·1	..	..	..	..

* The determinations were made in the Technological Laboratory of the Indian Central Cotton Committee, Bombay.

The results of spinning tests of some of these cottons, showing the highest counts of warp to which each could be spun economically (1924-25 season) with moderate twist were as under :—

Counts spun economically.

	s.
1027 A. L. F.	32
1027 × Goghari cross—	
No. 6	32
1-A × Goghari cross—	
No. 1	30
No. 5	22
No. 9	26

Similar results of some of these cottons from fifty pounds samples for 1925-26 were as under :—

Counts spun economically.

	s.	
1027 A. L. F.	28	
1027 × Goghari cross—		
No. 5	26	
No. 6	20	
1-A Cylindrical boll	20	barely
1-A Goghari cross, No. 9	20	

The spinning power does not entirely correspond with the tests of staple, and this is not unexpected, as the capacity to spin fine yarn is not *exclusively*, even with the same class of cotton, dependent on the length of staple.

E. Weight per seed and its relation with lint length and lint index.

The importance of this character is indirect. But it has been shown in a previous memoir that in these Gujarat *herbaceum* cottons there is a positive correlation between the weight of the seed and the weight of the lint on the seed. It does not, however, seem to have been studied by previous workers, though Dunlavy[1] has found that, in Texas cottons, it is clearly correlated with other characters as follows :—

Coefficient of correlation.

Lint index and seed weight	$+0{\cdot}70 \pm 0{\cdot}021$
Boll size and seed weight	$+0{\cdot}66 \pm 0{\cdot}034$
Staple length and seed weight	$+0{\cdot}43 \pm 0{\cdot}043$
Lint percentage and seed weight	$-0{\cdot}53 \pm 0{\cdot}038$

[1] *Jour. American Soc. Agri.*, Vol. XV, No. 11 (1923).

The present study is only concerned with the cross made between our types 1-A Cylindrical Boll and Goghari E-5, as in the other case there is no significant difference between the seed weights of the parents. The actual mean figures given by the parents in this case and the coefficient of variation is shown in the following table.

Weight of seed.

	1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation
	mg.		mg.	
1919-20	59·7	5·5±0·37	53·7	7·2±0·34
1920-21	59·4	5·1±0·34	53·6*	..
1921-22	62·9	..	60·9	..
1925-26	59·5	8·9±0·42	53·8	11·1±0·45

The difference between the mean value of the seed weight in the parents is distinct and constant. The distribution of the seed weights in 100 plants of each type in 1920-21 and in the first two generations of the cross is as follows (1920-21 and 1921-22).

Frequency of seed weights.

Seed weights	1-A Cylindrical boll	Goghari E-5	Cross F_1	Cross F_2
mg.				
36—40	..	..	..	..
40—44	..	..	..	1
44—48	..	6	4	2
48—52	..	28	9	
52—56	12	38	27	9
56—60	50	24	47	27
60—64	31	3	11	32
64—68	7	..	2	19
68—72	..	1	..	7
72—76	..	..	..	3
76—80	..	..	..	
80—84	..	..	..	
88—92	..	..	..	
Means	59·4 mg.	53·6 m.g.	60·2 mg.	61·5 mg.

* The seed weight of Goghari E-5 in 1920-21 is of the crop grown at Broach, not at Surat. As the seed weight of " 1-A Cylindrical Boll " is the same at Surat in 1919-20 and 1920-21, it is assumed that this would also be the case with the other parent.

The figures for the F_2 generation are, of course, not quite comparable with the others, as they were not for the same season, and the frequency distribution for the parents in 1921-22 is not available. But the figures do show the somewhat wider distribution and nearly symmetrical curve which would be expected in the second generation of a cross with a complex character.* The fact that the seed weights of the parents overlap so considerably precludes Mendelian analysis but a study of what happens in succeeding generations, by method previously adopted, may give interesting results. The figures for the first (F_1) generation of the cross, however, show that the seed weight is much higher than the mean of the parents and hence indicates at least partial dominance.

The results in succeeding generations were as follows :—

Third Generation (F_3). (1) Seed weight of parent plants.

1-A × Goghari cross—	mgm.
Plant 1	72
Plant 5	62
Plant 9	67

(2) Seed weight in the F_3 generation—

Frequency distribution with different types.

	44-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72 76 mg.	76-48 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll	Not recorded								62·2
Goghari E 5									59·1
1-A × Goghari cross—									
Plant 1	1	2	12	*35*	34	12	3	1	64·0
Plant 5	7	17	*33*	26	12	3	2	..	59·6
Plant 9	..	..	8	18	*32*	29	10	3	66·9

Fourth Generation (F_4). (1) Seed weight of parent plants—

1-A × Goghari cross—	mg.
Plant 1	70
Plant 5	59
Plant 9	58

* The coefficient of variation in " 1-A Cylindrical Boll × Goghari Cross " in the F_1 and F_2 generations is as follows :—F_1—coefficient of variation $6{\cdot}5 \pm 0{\cdot}5$; F_2 Coefficient of variation $8{\cdot}5 \pm 0{\cdot}2$. It is slightly greater in the F_2 generation.

(2) Seed weight in the F_4 generation—

Frequency distribution with different types.

	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72-76 mg.	76 84 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll . .	Not recorded								66·0
Goghari E-5 . . .									60·0
1-A × Goghari cross—									
Plant 1	2	4	6	27	27	18	13	3	65·8
Plant 5	..	..	..	..	..	..	..	..	..
Plant 9	1	5	25	25	20	17	7	..	63·5

Fifth Generation (F_5). (1) Seed weight of parent plants—

1-A × Goghari cross—	mg.
Plant 1	66
Plant 5	61·5
Plant 9	58·5

(2) Seed weight in the F_5 generation.

Frequency distribution with different types.

	44-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72-76 mg.	76-84 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll . .	Not recorded								64·6
Goghari E-5 . . .									62·9
1-A × Goghari cross—									
Plant 1	..	10	5	*41*	33	7	2	2	63·8
Plant 5	17	32	*42*	8	..	1	..	..	55·5
Plant 9	3	22	*58*	9	7	..	1	..	58·2

Sixth generation (F_6). (1) Seed weight of parent plants—

1-A × Goghari cross—	mg.
Plant 1	60
Plant 5	53
Plant 9	60

(2) Seed weight in the F_6 generation.

Frequency distribution with different types.

	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll .	1	..	..	1	4	9	20	47	8	59·5
Goghari E-5 . .	2	2	..	9	23	27	22	13	2	53·8
1-A × Goghari cross—										
Plant 1 . .	..	..	..	..	..	..	..	..	..	60·3
Plant 5 . .	2	9	13	29	34	4	9	..	..	51·2
Plant 9 . .	..	11	5	19	50	14	1	..	..	52·1

The mean values and the coefficients of variation in the last three generations will show how far clearly distinct types have been obtained. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean seed weight	Coefficient of variation	Mean seed weight	Coefficient of variation	Mean seed weight	Coefficient of variation
	mg.		mg.		mg.	
1-A Cylindrical boll . . .	·66	..	65	..	59·5	8·9±0·4
Goghari E-5	60	..	63	..	54	11·1±0·4
1-A × Goghari cross—						
Plant 1	66	9·0±0·4	64	8·2±0·6	60	..
Plant 5	..	..	55·5	7·3±0 3	51	10·4±0·5
Plant 9	63·5	8·6±0·4	58	6·4±0·4	52	9·0±0·3

Three conclusions with regard to the inheritance of seed weight seem to follow from this analysis of the record of these plants. They are :—

1. There appears at least partial dominance[1] in the direction of heavier seed weight as the F_1 generation shows considerable departure from the mean of the parents towards the heavier seeded variety.

2. The coefficient of variation in the F_1 generation is less than in the more varying parent, as well as in the F_2 generation ; though the difference is slight. Further, the distribution in the F_2 generation is nearly symmetrical. All these facts indicate that we are dealing with a complex character involving several-factors.[2]

3. By the F_5 and F_6 generation all the types obtained have a coefficient of variation lower than that of the parents, and may hence be taken as pure for this

[1] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull.* 1164 (1923), p. 53.

[2] East. Studies in size inheritance in Nicotiana. *Genetics*, Vol. I, p. 164 (1916).

character. It will be noticed that the progeny of plant No. 1 has regained almost exactly the position of the parent 1-A Cylindrical boll; the progeny of plants 5 and 9, on the other hand, gave in two successive generations *below* the figure for the Goghari E-5 parent. The latter fact is of particular interest, as it may show possibilities of achieving a break up of this character, enabling us to go beyond the point occurring in *either* parent.

Correlation of seed weight with other characters. An attempt was made to use the figures obtained in this study to ascertain whether there is genetic correlation between the seed weight and two other characters, namely, the staple or lint length of the cotton, and the lint index, or the amount of cotton per 100 seeds. For this purpose the test proposed by Collins[1] was used, namely, the comparison between the coefficients of correlation in the F_2 and in the F_1 generation of the cross. It is assumed that if the coefficient of correlation in the F_2 generation significantly exceeds that in the F_1 generation, in the direction indicated by the relation of the parental means, coherence of characters (or genetic correlation) is indicated.[2]

The results of applying this test were as under :—

Characters	Coefficient of correlation	
1-A × Goghari cross	F_1	F_2
Seed weight and lint length	$+0{\cdot}20 \pm 0{\cdot}10$	$+0{\cdot}23 \pm 0{\cdot}04$
Seed weight and lint index	$+0{\cdot}71 \pm 0{\cdot}07$	$+0{\cdot}45 \pm 0{\cdot}03$

The relation between seed weight and lint length in the F_1 generation is slight, and is hardly altered in the F_2 generation. This indicates that there is no coherence of these characters. On the other hand, the relation between seed weight and the lint index appears strong and positive in the F_1 generation, and less strong but still positive in the F_2 generation. The correlation is, however, in the *opposite* direction to that shown in the parents. We are, therefore, driven to the conclusion that in this pair of characters also there is no genetic correlation, and that any correlation shown by the figures is purely physiological.

F. Lint index and its relation to lint length.

The lint index is the weight of lint per 100 seeds of cotton. It represents the productive capacity of the plant in lint, when considered along with the number of seeds. It has, however, not been separately examined as a special character by many workers. The more usual character studied has been the "ginning percen-

[1] Collins. Correlated characters in maize breeding. *Jour. Agri. Res.*, Vol. VI, p. 439 (1916).
[2] Kearney & Wells. *American Naturalist*, Vol. LII, p. 501 (1918).

tage ", or the proportion the weight of lint bears to the combined weight of lint and seed. This latter, though of great practical importance is, after all, a ratio, and, in fact, the ratio between two variables. It will be dealt with later, but in the meantime it may be stated that Harland[1] and Hodson[2] have found that there is a close correlation between the ginning percentage and the lint index.

Other investigations into the matter are those of Balls[3] who found that a regular distribution of lint in the seed is dominant over irregular distribution. Balls, however, makes no statement regarding the quantity of lint. Kearney (*loc. cit.*) in Holdon—Pima hybrids give figures which seem to indicate that a low lint index is at least partially dominant.

In the figures which follow, it will be noticed that the variability even of pure types is very considerable and this is what would be expected. The amount of lint on the seed, though it may partially result from the genetic constitution of the parents, yet will be obviously very largely determined by the conditions of growth and ripening. With this note, the actual figures for the parents, in this character for a series of years, with the coefficient of variation may be given.

Lint index.

	1027 A. L. F.		1-A Cylindrical Boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	mg.		mg.		mg.	
1919-20	32	11·0±0·8	38	8·2±0·5	57[4]	9·7±0·6
1920-21	34	9·4±0·6	38	8·4±0·6	57	..
1921-22	33	..	38	..	59	..
1922-23	30	..	40	..	55	..
1923-24	35	..	41·5	..	60	..
1924-25	33	..	38	..	57	..
1925-26	32	9·0±0·4	36	9·5±0·4	46	13·8±0·7

[1] *Agri. News of the West Indies*, May 20th, 1916 (page 166).

[2] Hodson. Correlation of certain characters in cotton. *Arkansas Agric. Expt. Stn. Bull.* 169 (p. 15).

[3] Note on Mendelian studies in Egyptian cotton. *Jour. Agri. Sci.*, Vol. II (1908).

[4] In 1919-20—1920-21 the results of " Goghari E-5 " were obtained from the crop at Broach. The remainder were grown at Surat.

The difference between the parents with regard to this character is hence very great. The Goghari E-5 has a *very* high lint index, by far the greatest, in fact, in any known type of *Gossypium herbaceum*. The other parent, in each case, has a considerably lower value. In the first generation (F_1) of the crosses, the distribution and mean of this character in the progeny is shown below.

LINT INDEX—F_1 GENERATION.

Frequency distribution.

	28-32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	Over 64 mg.	Mean mg.
1027 A. L. F.	30	43	22	5	..	..	..	..	..	..	33·9
1-A Cylindrical boll	2	23	48	21	6	..	..	..	..	..	38·2
Goghari E-5	..	..	..	1	2	16	21	22	31	8	57·3
1027 × Goghari cross	..	..	9	9	26	17	26	9	4	..	49·5
1-A × Goghari cross	..	..	7	9	11	33	31	9	..	..	49·8

The F_1 generation is therefore intermediate between the parents but with a tendency towards the parent with the higher lint index. The mean of the parental values in the 1027 × Goghari cross is 45·6 mgm., and in the 1-A × Goghari cross is 47·7 mgm.

Second Generation (F_2). The distribution of the value of the lint index in the second generation of the cross is as follows :—

LINT INDEX—F_2 GENERATION.

Frequency distribution.

	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	Mean mg.
1027 A. L. F.	Not recorded									32·8
1-A Cylindrical boll										38·0
Goghari E-5										58·9
1027 × Goghari cross	2	5	11	18	26	23	11	3	1	49·8
1-A × Goghari cross	1	6	8	18	28	23	11	4	1	50·3

It will be noticed that the frequency distribution in the F_2 generation is nearly symmetrical, suggesting that the character is composed of several factors. The coefficient of variation is only a little greater than in the F_1 generation, as the following figures show.

Coefficient of variation.

	F_1	F_2
1027 × Goghari cross	12·5±1·25	12·6±0·35
1-A × Goghari cross	11·0±0·79	12·4±36·0

This also suggests complexity in the character studied.

The figures for plants selected as described under previous characters in the next four generations may now be given.

Third Generation (F_3). (1) lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	42
Plant 6	46
1-A × Goghari cross—	
Plant 1	52
Plant 5	53
Plant 9	54

(2) Lint index in F_3 generation –

Frequency distribution.

	28-32 mg.	32 36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg	60-64 mg.	Over 64 mg.	Mean mg.
1027 A. L.F.	Not recorded										30
1-A Cylindrical boll											40
Goghari E-5											55
1027 × Goghari cro-s—											
Plant 5	..	10	14	34	21	14	5	2	..	..	43·5
1-A × Goghari cross—											
Plant 1	1	..	4	16	32	34	12	1	..	..	47·4
Plant 5	1	..	2	7	20	37	28		2	2	50·5
Plant 9	..	8	11	34	37	10	..	..	..	..	43·1

Fourth Generation (F_4). (1) Lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	50
Plant 6	49
1-A × Goghari cross—	
Plant 1	51
Plant 5	43
Plant 9	45

(2) Lint index in F_4 generation—

Frequency distribution.

	28-32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	Mean mg.
1027 A. L. F.	Not recorded											35
1-A Cylindrical boll												41·5
Goghari E-5												60
1027 × Goghari cross—												
Plant 6	..	3	9	29	33	8	5	..	..	..	..	45
1-A × Goghari cross—												
Plant 1	1	2	7	13	14	29	12	12	7	1	2	50
Plant 9	..	1	11	21	35	26	5	1	..	..	..	46

Fifth Generation (F_5). (1) Lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	45
Plant 6	43·5
1-A × Goghari cross—	
Plant 1	44
Plant 5	47
Plant 9	41

(2) Lint index in F_5 generation.

Frequency distribution.

	28-32 mg.	32-36 mg.	36 40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52 56 mg.	Mean mg.
1027 A. L. F.	Not recorded							33
1-A Cylindrical boll								3
Goghari E-5								57
1027 × Goghari cross—								
Plant 5	4	4	18	44	28	2	..	41
Plant 6	2	2	8	35	47	4	2	44
1-A × Goghari cross—								
Plant 1	2	14	53	27	2	2	..	39
Plant 5	1	8	13	43	35	..	..	42
Plant 9	..	..	7	49	38	3	3	44

Sixth Generation (F_6). (1) Lint index of parent plant—

	mg.
1027 × Goghari cross—	
Plant 5	37
Plant 6	44
1-A × Goghari cross—	
Plant 1	42
Plant 5	53
Plant 9	45

(2) Lint index in F_6 generation.

	20-24 mg.	24-28 mg.	28 32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	Mean mg.
1027 A. L. F.	1	6	35	*49*	8	1	..	..	..	..	32
1-A Cylindrical boll	1	2	11	36	*44*	6	..	..	..	..	36
Goghari E-5	..	1	1	5	12	18	22	*25*	14	2	46
1027 × Goghari cross—											
Plant 5	4	5	8	13	24	*29*	16	1	..	..	38
Plant 6	2	3	6	7	19	*33*	27	3	..	..	40·5
1-A × Goghari cross—											
Plant 1	Not recorded										39
Plant 5	..	1	8	17	17	*30*	23	4	..	..	40
Plant 9	..	3	8	7	23	*47*	10	2	..	..	40

The mean values and the coefficients of variation in the last three generations will show how far, clearly distinct types have been isolated. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean lint index	Coefficient of variation	Mean lint index	Coefficient of variation	Mean lint index	Coefficient of variation
	mg.		mg.		mg.	
1027 A. L. F.	35	..	33	..	32	9·0±0·4
1-A Cylindrical boll	41·5	..	38	..	36	9·5±0·4
Goghari E-5	60	..	57	..	46	13·8±0·7
1027 × Goghari cross—						
Plant 5	..	..	41	10·1±0·7	38	16·5±0·5
Plant 6	45	9·5±0·6	44	8·6±0·6	41	13·8±0·6
1-A × Goghari cross—						
Plant 1	50	15·9±0·7	39	8·8±0·6	39	..
Plant 5	..	..	42	9·2±0·4	40	13·3±0·7
Plant 9	46	9·9±0·4	44	7·0±0·4	40	12·1±0·5

In 1925-26 the lint index decreased in all cases, and was very highly variable, as the ripening conditions were very abnormal. Judged by the coefficient of variation, however, all the types isolated have now bred true. But it is clear that al the pure segregates obtained have a value for the lint index intermediate between that of the parents. This does not mean that types do not exist with the parental values or even with extra parental values. But they have not been isolated, and the prevalence of the intermediate values shows the complexity of the inheritance of the character we are studying.

On account of the high variability in 1027 × Goghari cross, Plant 5, the parent-offspring correlation was worked out in this case. The result gave a correlation coefficient of $-0{\cdot}03 \pm 0{\cdot}10$. In other words, the segregate is pure regarding this character.

Correlation of Lint Index with Lint Length (*Staple*). The figures obtained in the F_2 and F_1 generations of these crosses have enabled us to apply the test proposed by Collins and described on (page 162) above, to see whether there is any coherence of the lint index and the lint length in the strains crossed. In this test[1] it is assumed that if the coefficient of correlation between these characters in the F_2 generation significantly exceeds that in the F_1 generation in the direction indicated by the relations of the parental means, coherence of characters is indicated. The results of applying this test in the present case are as under :—

Character	Coefficient of correlation	
	F_1	F_2
Lint index and lint length.—		
1027 × Goghari cross	$+0{\cdot}39 \pm 0{\cdot}12$	$-0{\cdot}23 \pm 0{\cdot}04$
1-A × Goghari cross	$+0{\cdot}14 \pm 0{\cdot}10$	$-0{\cdot}36 \pm 0{\cdot}03$

These figures make it clear that there is no genetic coherence between these two characters.

G. Ginning percentage and its relation with length of staple

The ginning percentage of any type of cotton, that is to say, the relation of the weight of lint to the whole weight of the seed cotton (*kapas*) is almost obviously a complex character being the ratio of two variables, which vary with almost if not entirely complete independence. Where the *seed* weight of the two types compared is similar, then the ginning percentages vary almost exactly in the same manner as the lint index. This is the case which occurs when the types 1027 A L. F. and Goghari E-5 are compared and crossed. When the seed weight of the parents differ, as in the other cross under study (1-A Cylindrical Boll and Goghari E-5), the inheritance of ginning percentage is obviously an extremely complicated matter. Owing, however, to the extreme practical importance which attaches to the ginning percentage it may be worth while to follow the behaviour of this ratio when the types of cotton under study are crossed.

[1] Kearney & Wells. *American Naturalist*, Vol. 52. 1918.

The actual figures for the ginning percentage of the parents of the crosses were as follows :—

Ginning percentage.

	1027 A. L. F.		1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	Per cent.		Per cent.		Per cent.	
1919-20	33·5	6·8±0·5	38·8	4·7±0·3	51·6*	2·7±0·1
1920-21	34·9	5·2±0·3	39·3	3·8±0·2	51·6*	..
1921-22	36·2	..	37·7	..	49·8	..
1922-23	33·5	..	39·0	..	48·1	..
1923-24	36·4	..	38·6	..	49·6	..
1924-25	35·8	..	36·9	..	47·6	..
1925-26	37·1	4·7±0·2	37·3	3·6±0·2	45·6	4·6±0·2

The difference between the parents is hence very great, and there is practically no overlapping. The Goghari E-5 has a *very* high ginning percentage, the highest, in fact, of any known type of *Gossypium herbaceum*. In the first generation (F_1) of the crosses, the distribution and mean value of this character in the progeny is shown below.

Ginning percentage—F_1 Generation.

Frequency distribution.

	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52	52–54	54–56	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F. . .	2	5	18	*42*	33	..	..	..	..	..	..	..	..	..	34·9
1-A Cylindrical boll .	..	..	..	4	11	*54*	27	4	..	..	..	..	..	..	39·3
Goghari E-5 . .	..	..	..	..	..	..	..	..	1	..	8	*50*	39	2	51·6
1027 × Goghari cross .					4	13	31	17	*35*	..	..	..	..	..	44·3
1-A × Goghari cross .	..	..	..	.	..	..	9	13	*45*	33	..	..	..	..	45·1

* In 1919 20, and in 1920-21, the results of Goghari E-5 were obtained from the crop at Broach.

The F_1 generation is, therefore, intermediate between the parents, but shows a very slight tendency towards the higher ginning parent. The mean of the parental values in the 1027 × Goghari cross is 43·3 per cent. and in the 1-A × Goghari cross is 45·4.

Second Generation (F_2). The distribution of the value of the ginning percentage in the second generation of the cross is as follows :—

GINNING PERCENTAGE— F_2 GENERATION.

Frequency distribution.

	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50 52	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	}							}	36·2
1-A Cylindrical boll	}				Not recorded			}	37·7
Goghari E-5	}							}	49·8
1027 × Goghari cross	2	6	8	22	27	23	10	2	44·7
1-A × Goghari cross	3	4	5	22	28	27	11	..	44·9

The frequency distribution in this generation is nearly symmetrical in both cases, suggesting that the character is composed of several factors. The variability is slightly higher than in the F_1 generation, the figures being as follows :—

	Coefficient of variation	
	F_2	F_2
1027 × Goghari cross	5·2 ± 0·5	6·7 ± 0·2
1-A × Goghari cross	4·0 ± 0·3	6·2 ± 0·3

The figures for plants selected as already described under previous characters in the next four generations may now be given.

Third Generation (F_3). (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	42·6
Plant 6	43·1
1-A × Goghari cross—	
Plant 1	42·1
Plant 5	46·0
Plant 9	40·0

(2) Ginning percentage in F_3 generation—

Frequency distribution.

	30-32	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded										33·5
1-A Cylindrical boll											39·0
Goghari E-5											48·1
1027 Goghari cross											
Plant 5	2	0	1	*31*	24	12	10	0	..	..	38·0
1-A × Goghari cross—											
Plant 1	..	..	..	2	13	22	*40*	18	5	..	42·5
Plant 5	..	..	1	..	1	1	12	29	*42*	14	46·1
Plant 9	..	5	3	*29*	24	21	18	..	..	..	39·2

Fourth Generation (F_4) (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	42·
Plant 6	41·9
1-A × Goghari cross—	
Plant 1	42·4
Plant 5	42·5
Plant 9	43·8

(2) Ginning percentage in F_4 generation—

Frequency distribution.

	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50-52	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded									36·4
1-A Cylindrical boll										38·6
Goghari E-5										49·6
1027 × Goghari cross—										
Plant 6	2	32	*31*	27	5	..	..	..	..	39·3
1-A × Goghari cross—										
Plant 1	1	9	13	17	*19*	15	14	9	3	43·1
Plant 9	..	4	18	32	*33*	11	2	..	..	41·7

Fifth Generation (F_5). (1) Ginning percentage of parent plants--

	Per cent.
1027 × Goghari cross—	
Plant 5	37·5
Plant 6	39·2
1-A × Goghari cross—	
Plant 1	40·4
Plant 5	43·4
Plant 9	41·5

(2) Ginning percentage in F_5 generation—

Frequency distribution.

	34-36	36-38	38-40	40-42	42-44	44-46	46-48	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded							35·8
1-A Cylindrical boll								36·9
Goghari E-5								47·6
1027 × Goghari cross—								
Plant 5	4	29	43	20	4	..	..	39·0
Plant 6	4	8	35	23	10	..	..	39·9
1-A × Goghari cross—								
Plant 1	7	41	43	9	..	..	..	38·1
Plant 5	..	2	2	19	43	34	..	43·1
Plant 9	..	..	1	20	60	18	1	42·9

Sixth Generation (F_6). (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	38·5
Plant 6	40·5
1-A × Goghari cross—	
Plant 1	41·1
Plant 5	44·3
Plant 9	42·9

(2) Ginning percentage in F_6 generation—

	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F. . .	5	21	*43*	26	5	..	..	..	..	37·1
1-A Cylindrical boll .	2	15	*50*	32	1	..	..	..	..	37·3
Goghari E-5 . .	..	..	..	3	2	12	*39*	32	12	45·6
1027 × Goghari cross—										
Plant 5 . .	..	5	14	29	*35*	17	..	..	..	39·9
Plant 6 . .	..	1	7	20	*46*	23	3	..	..	40·9
1-A G ghari cross—										
Plant 5 . .	..	..	..	2	17	*35*	30	15	1	43·9
Plant 9 . .	..	..	1	4	21	*38*	32	4	..	43·1

The mean values and the coefficients of variation in the last three generations will show how far clearly distinct types have been isolated. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean Ginning percentage	Coefficient of variation	Mean ginning percentage	Coefficient of variation	Mean ginning percentage	Coefficient of variation
	Per cent.		Per cent.		Per cent.	
1027 A. L. F.	36·4	..	35·8	..	37·1	4·7±0·2
1-A Cylindrical boll . . .	38·6	..	36·9	..	37·3	3·6±0·2
Goghari E-5	49·6	..	47·6	..	45·6	4·6±0·2
1027 × Goghari cross—						
Plant 5	..	..	39·0	4·3±0·3	39·9	5·5±0·2
Plant 6	39·3	4·7±0·3	39·9	4·5±0·3	40·9	4·7±0·2
1-A × Goghari cross—						
Plant 1	43·1	8·7±0·4	38·1	4·2±0·3	39·2	..
Plant 5	..	..	43·0	3·9±0·2	43·9	4·8±0·2
Plant 9	41·7	5·3±0·2	42·9	3·7±0·2	43·1	4·3±0·2

It will first of all be noticed that all values in the crosses are intermediate between the parents, and this is the case although the types isolated seem, as judged by the coefficient of variation, to be pure in this character. One type of each cross approaches the value of the lower ginning parent ; the others, while clearly intermediate, are more nearly approaching the higher ginning parent. Among the type isolated there is no sign of any which goes beyond either parent.

Correlation of ginning percentage with other characters.

An attempt was made to use the figures obtained in this study to ascertain whether there is genetic correlation, or coherence of characters, between the ginning percentage and the staple of the lint. There is a very widespread impression among cotton growers that a high ginning percentage is almost, if not entirely, inconsistent with a long staple cotton. There has, hitherto, been no positive evidence in favour of this view. In fact, what evidence exists, seems to show that the two characters vary independently. The application of the test proposed by Collins (p. 162) in the present case may give some information on the point.

If we compare the correlation between the two characters concerned—ginning percentage and staple—in the F_1 and F_2 generations, genetic correlation would be shown if there is greater intensity of correlation in the F_2 generation, in the same direction as occurs in the parents. The following are the figures actually obtained.

Coefficient of correlation between ginning percentage and staple.

	F_1	F_2
1027 × Goghari cross	+0·31±0·1	—0·35±0·03
1—A × Goghari cross	—0·39±0·1	—0·60±0·03

So far as the 1027 × Goghari cross is concerned, there is no evidence of any coherence between these characters. In the 1-A × Goghari cross the result is not so clear, and there is marked intensification in the correlation in the F_2 generation in the same direction as occurs with the parents. The result tends to show that in certain cottons only there is reason to suspect some coherence between the two characters dealt with. The matter, however, requires much more investigation and the application of the test in many other cases. If such further investigation confirms the result just given, it may indicate a reason for the apparent difficulty in combining maximum ginning percentage with the highest staple.

III. General conclusions.

The object of the work reported in the present memoir was deliberately and definitely the production of a type of cotton for the Surat and Broach Districts, which while retaining the staple and quality of the present fibre should, at the same time, have a higher ginning outturn. This has been successfully accomplished in the case of a cotton suitable for Broach and this is now being multiplied for distribution on a large scale. A similar result appears also to have been achieved in connection with cottons suitable for Surat, though it is not quite certain whether the spinning value of the typical high class Surat cotton (1027 A. L. F.) has been retained.

Incidental to the above practical object, the data collected have been employed to study seven characters of the cotton plants used as parents of two crosses between pure types of Broach-*deshi* (1027 A. L. F. and 1-A Cylindrical boll) and of Goghari (E-5) Cottons,—all being strains of *Gossypeum herbaceum*, and also the same characters in six generations of the resulting crosses. The main objects of the study were two, as follows :—

(*a*) To determine whether the characters studied are simple Mendelian characters which can be transferred without change from plant to plant, or are complexes of a number of factors which, while normally inherited together, may be separated in the course of inheritance.

(*b*) To ascertain whether the several characters studied are genetically correlated, that is to say, whether there is coherence of these characters during inheritance.

The results of the enquiry dealing as it does with the following characters may now be given :—

(*a*) *Node in the Stem from which the first Sympodium arises.* This character, when fixed definitely in the fifth and sixth generation of the cross, conforms to one or other of the parents, except in one case. In this case, the node is higher on the stem than that of either of the parents. This indicates that we are dealing with a complex character, of which the elements cohere closely. But it shows the possibility of being able by crossing to obtain a form of plant different from the parents and suited to particular conditions.

(*b*) *Diameter of the Bolls.* A large boll is an advantage, and hence the interest of the present study in this respect. Out of five types followed out to the sixth generation of the cross, two conform to one or other of the parents. Two are intermediate between them, out of which the purity of one is doubtful. The fifth, however, has a larger boll than either of the parents from which it is produced, and yet it definitely breeds true. This indicates that the maximum diameter of the bolls is a complex character. But it shows the possibility of being able by crossing to obtain a larger boll than that of either parent,—a result achieved in the present case.

(*c*) *Shape of the Boll.* The shape of the boll, as judged by the boll index, has proved itself again a complex character which *may*, from the evidence, be composed of two factors. All the plants obtained, when the types were found to be fixed (as judged by means of the coefficient of variation), conformed, however, in this character to one or other of the parental types, and thus indicated the very close linkage of the factors which determine the shape of the boll.

(*d*) *Length of Staple.* When stable and fixed types of plant in respect to lint length are obtained in the fifth and sixth generation of the cross, it was found that out of five types obtained three conformed almost exactly to the type of one of the parents, one was intermediate between the parents, and one has a staple distinctly longer than the longer parent. This indicates that we have to deal with a complex character, and indicates the possibility of obtaining by crossing types of longer staple than any of those which are now grown, and which could be used as parents.

(*e*) *Weight of Seed.* The weight of the seed proves to be a complex character, with at least partial dominance in the direction of heavier seed weight. There are indications that it is possible to obtain types with seed weight lower than either of the parents, a fact which opens up new possibilities in cotton breeding. There appears to be no genetic correlation in the cottons examined between the seed weight and either the lint length or the lint index.

(*f*) *Lint index* or the weight of lint per one hundred seeds. In this matter all pure types of the cross isolated have values intermediate between those of the parents. This does not mean that strains do not exist with the parental values or even with values beyond these latter, but it does indicate the complexity of the character. There appears to be no genetic correlation between the lint index and the lint length.

(*g*) *Ginning Percentage.* This character, which is really only a ratio between the lint index and the total weight of the seed and lint together is only studied because of its commercial importance. As would be expected from the results with the lint index, the values obtained in the cross are all intermediate between the parents. There seems some evidence of a partial coherence between this character and the lint length in a negative direction, in certain cases only.

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